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THE ACHROMATIZATION OF APPROXIMATELY MONOCHROMATIC INTERFERENCE FRINGES BY A HIGHLY DISPERSIVE MEDIUM, AND THE CONSEQUENT INCREASE IN THE ALLOWABLE PATH-DIFFERENCE.

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Presented by C. R. Cross, October 12, 1904. Received September 6, 1904.

The results recorded in the present paper were, for the most part, obtained during the progress of an investigation of the dispersion of sodium vapor. As I have mentioned in the previous paper, the path-difference under which it is possible to obtain interference-fringes with helium (D_3) light can be more than doubled by the introduction of a small amount of sodium vapor into the path of one of the interfering beams. This development of fringes far out in the system by the dispersive action of the vapor is accompanied by their complete disappearance at the centre of the system, where the difference of path is zero.

In order to understand this action of the vapor we must first consider briefly the conditions under which fringes may be visible.

Suppose that we have a system of circular fringes formed with white light, and consider a point just outside of the visible ring system, where the illumination appears uniform. Our fringe system is built up of an infinite number of colored systems which are in coincidence at the centre, but which get more and more out of step as we advance out into the system, owing to the fact that the "scale" on which the Newton rings are formed decreases with decreasing wave-length. Let us now consider in what manner fringes may be made to appear at a point where the overlapping is so great as to destroy all trace of the fringes; in other words, how may achromatization be more or less completely secured.

It appears to me that there are only two conceivable ways in which the result can be obtained. If we could, by the introduction of a dispersing medium, increase the diameters of the blue rings without generally affecting the diameters of the red ones, it is obvious that we should greatly increase the number of visible fringes without, however, altering their distinctness at the centre of the system.

A slight inclination of either of the back mirrors of the interferometer increases or diminishes the scale on which the fringes are formed, and since a similar change in the direction of the reflected rays can be effected by the introduction of an acute prism, it is easy to see that, owing to the dispersion of the latter, the change in the scale will be different for the different wave-lengths, more or less perfect achromatization resulting.

The introduction of a medium into the path of one of the interfering beams causes a shift of the fringe system as a whole, and if the medium is dispersing the shifts will be different for the different colors. The red, green, and blue fringes, which are out of step at a given point, may thus be brought into coincidence by the inequality of their respective displacements. In this case, however, since the systems are shifted as a whole, the fringes will be thrown out of step at the centre of the system, consequently we have obtained an increase in the distinctness far out in the system, at the expense of distinctness at the centre. This is precisely what happens in the case which we are considering.

It has been found in every case that the introduction of sodium vapor into one path of the interferometer increases the distinctness of the fringes in a portion of the system which is brought into the field of the instrument by increasing the length of the other path.

We will now consider the case of the helium fringes, which under ordinary circumstances disappear when the path difference is between 1.5 and 2 cms., there being no recurrence of visibility by further increment of path difference, as in the case of sodium light. We must therefore regard the helium (D_3) line as a single line of finite breadth or a close group of lines. In Figure 1 let BC represent the intensity curve of the helium light, C being the edge of shorter wave-length. Immediately above we have a schematic representatation of the fringe system, with its centre at A. Light from the side B of the D_3 line will produce the fringes indicated by the dotted line, which are farther apart than the fringes formed by the light of shorter wave-length coming from the side C of the line. There will, in addition, be an infinite number of other systems formed by light of wave-lengths intermediate between B and C which I have indicated by light shading.

Now suppose sodium vapor to be introduced into one path of the instrument, and the whole system shifted slightly to the left in consequence. Owing to the enormous dispersive power of the vapor, the dotted system (longer λ's) will be shifted more than the other, since the D_3 line lies on the blue side of the sodium absorption-band, and the change in the velocity of the light is greatest for the longest waves, namely, those on the B side of the line. The result of this dispersive action is that the fringes are brought into step at a point D, to the right of the centre, thrown out of step at the centre, and still more out of step to the left of the centre. If we had but the two systems indicated by the solid and dotted lines, it is obvious that the systems would come into step again to the left of the centre, a condition which would occur if D_3 consisted of two infinitely narrow lines very close together. In the actual case the presence of waves of lengths intermediate between those of B and C make such a recurrence of visibility to the left of the centre impossible, and we have distinct fringes to one side only of the original centre of the system. On increasing the density of the sodium vapor, the point D of maximum visibility moves further along to the right, and to keep the fringes in the field it is necessary to turn the screw of the instrument in such a direction as to cause the system to move in *the same direction* as the shift due to the sodium vapor.

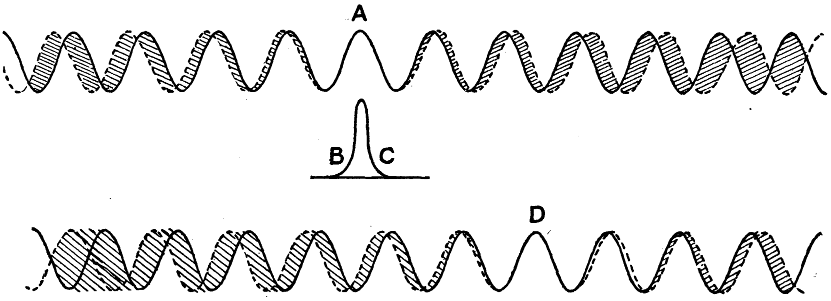

FIGURE 1.

Now the sodium vapor accelerates the helium light, since its refractive index is less than unity for light of shorter wave-length than that of D_2, consequently the reduced path is less. To shift the fringes in the same direction as that resulting from the shortening of the path through the sodium vapor, we must *lengthen* the other or air-path, which is precisely what was found to be the case, as I have already said.

If the D_3 line lay on the other side of the D lines, the shift would be in the opposite direction, i. e. to the right, and we might at first sight expect the point of maximum visibility to shift to the left of the centre. We must, however, remember that in this case the change of velocity is greatest for the *shortest* waves on the side C of the line; consequently the system indicated by the solid line will suffer the greatest displacement, and we shall have coincidence at D, to the right of the centre, exactly as before. To test this point experimentally, the interferometer was illuminated with light from the monochromatic illuminator, a narrow band on the green side of the D lines being utilized. The formation of sodium vapor in one of the paths gave rise to the same changes as were produced in the case of the helium light, it being necessary to increase the air-path to prevent the fringes from disappearing. If the fringes were made very narrow, so as to occupy only a small portion of the field, the wandering of the system to one side could be easily watched, as the sodium vapor was formed. It must be understood that only a very small actual *displacement* occurs, the wandering of the system being merely a change in position of the region over which fringes can be seen. On repeating the experiment with a band of approximately monochromatic light on the red side of the D lines, a similar drift of the position of maximum visibility was observed, and the direction of the drift was the same as before. In the case of helium light I have been able to increase the path difference to five or six centimeters, or to nearly treble it.

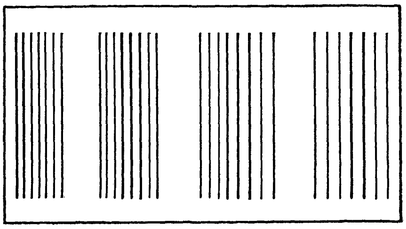

FIGURE 2.

The achromatizing action of the sodium vapor is most beautifully shown if we illumine the interferometer with white light.

Under ordinary conditions only two or three white fringes are seen, bordered on each side by perhaps a dozen rainbow-colored bands, which fade rapidly into a uniform illumination. If sodium vapor is formed in one of the interferometer paths, the colored fringes rapidly achromatize, and increase in number, breaking up, however, into groups, as shown in Figure 2. As the density of the vapor increases the number of groups increases, each group, however, containing fewer fringes. The position of the centre of the grouped system drifts in the same direction, as the point of maximum visibility in the previous experiments.

The explanation of the altered appearance of the fringes in this case is not as simple as in those previously considered. We are dealing with two wide ranges of wave-lengths on opposite sides of the absorption-band. The fringe shifts of the two spectral regions will be in opposite directions, while the drifts of the points of maximum visibility will be in the same direction. It appeared as if this might increase the width of the region over which fringes could be observed, for the red-orange fringes are shifted in one direction and the yellow-green in the opposite. Each set would be more or less perfectly achromatized, and in the region in which they overlapped we should expect a periodic visibility, owing to the difference in the widths of the fringes of the two systems.

To test the point it seemed best to work with a narrow range of the spectrum symmetrical about the D lines. This was obtained by opening the slit of the monochromatic illuminator, bisecting it with a wire, and adjusting the prisms so that the region of the D lines was screened off by the wire. By means of a small screen either of the two narrow portions of the spectrum bordering the D lines could be screened off.

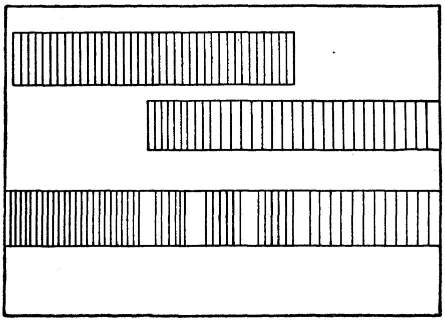

Figure 3.

The effect of the sodium vapor on the fringes formed when the interferometer was illumined by either one or both of the two portions of the spectrum could then be studied at leisure.

It was found that when a considerable amount of the vapor was present the apparent centre of the greenish-yellow fringe system was widely separated from the centre of the orange-yellow system.

When both sorts of light were used at once there was a periodic visibility in the region in which the two systems overlapped, the appearance in the three cases being shown in Figure 3.

The case is a little more complicated when white light, or the entire spectrum, is used, but it does not differ materially from the special case just considered.

Practically the same thing occurs when the interferometer is illuminated with sodium light, except that in this case the density of the sodium vapor in the optical path must be very much smaller. A periodic visibility results even when the light of one of the D lines is removed by the polarizing system described in the previous paper. The case is of course similar to the last-mentioned, for the width of the D line illuminating the instrument is greater than the width of the absorption-band of the rare vapor. We thus have a condition identical with that which we had when the emitting slit of the monochromatic illuminator was bisected with a wire which cut out the D lines from the narrow band of the spectrum which was utilized.